Statistical Process Control in Service Industry An Application with Real Data in a Commercial Company

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Abstract- The main purpose of this article is to present the advances of Statistical Process Control techniques in non-manufacturing processes. Specifically, in this article we present two applications of control charting techniques in a commercial company. The first is an application of control charting techniques in the Sales Department and the second is an application of control charts in the Logistic Departments.

Index Terms- Quality Control; Process Control; Service Industry; Multivariate Control Charts; Process Flow; Quality Control Implementation; Service Quality; Statistical Process Control; Statistical Quality Control; Services.

I. Introduction

The principal application domain for statistical process control (SPC) charts has been for process control and improvement in manufacturing businesses for about fifty years. The most common process control technique has been control charting.

A control chart is a useful statistical tool that aids practitioners in statistically controlling and monitoring one or more variables, when the quality of the product or the quality of the process is characterized by certain values of this or these variables. By the term controlling, we mean the ability of the control chart at any time to determine if the process or the product characteristic is statistically "in control". The term statistically "in control" process reflects to a process that operates with only chance causes of variation. A process that is operating in the presence of assignable causes is said to be statistically "out-of-control".

In General, a control chart is very easy to be implemented in any type of process. Thus, control charts are extensively used in manufacturing area nowadays, preserving the quality of the process or the final product. The controlling and monitoring is done over either the mean level or the variance of the process or quality characteristic. Montgomery [14] provides an excellent discussion about statistical process control procedures in the manufacturing industry.

However, the number of applications reported in domains outside of conventional production systems has been increasing in recent years. Implementing SPC chart approaches in non-standard applications gives rise to many potential complications and poses a number of challenges.

Woodall and Montgomery [19] note that there is a continuing need for publications of case studies showing the benefits of SQC generally.

Till the year 2004, more than 80 articles, have been identified in the literature that deal with non-standard applications of SPC charts. Broadly four application domains are mainly identified: (1) engineering, industrial and environmental applications; (2) healthcare applications; (3) general service sector application; (4) statistical applications.

Four principal objectives have been identified for the reported studies: (1) Process monitoring. This is an extension of the conventional applications of control charts to a much wider range of processes. As with conventional applications, the objectives are to monitor and control a process in order to maintain process stability and in many cases to enable process improvement. For this group of applications it is worth distinguishing between those applications for which conventional Shewhart charting techniques are deemed appropriate and those applications that require other techniques. (2) Planning. SPC charts are used in a number application domains to derive effective plans or schedules, particularly for maintenance scheduling. This may be a type of application for SPC charts with potential for wider use. (3) Evaluating customer satisfaction. SPC charts are used to evaluate customer satisfaction in a range of application domains to detect high levels of satisfaction and dissatisfaction. This may also be a type of application for SPC charts with potential for wider use. (4) Forecasting. SPC charts are used to generate or optimise a forecasting model. This may be considered a statistical or technical application of SPC charts with some potential for wider use specifically in forecasting applications.

In this article we present the advances of Statistical Process Control techniques in non-manufacturing processes. Specifically, in Section 2, we give a brief review of the literature in the area of non-manufacturing applications of statistical process control. Furthermore, in Section 3 we briefly discuss the main characteristics of Shewhart type control charts. Finally, in Section 4, we discuss an application of control charting techniques in the Sales Department. Finally, in Section 5 we point out some concluding remarks and topics for further research.

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II. Review

A number of researchers have proposed frameworks, implementation steps or given caveats for practitioners, who want to implement control charts in various non-manufacturing domains (Atienza et al. [1]; Beamon and Ware [2]; Benneyan [3,4] Does et al. [6]; Duffuaa and Ben-Daya [8]; Finison et al. [9]; Humble [11]; Lewis [12]; Roes and Dorr [15]; Sellick [16]; Wood [18]). Beamon and Ware [2] propose a framework which provides a methodology to implement a quality system for a supply chain process. Wood [18] proposes SPC chart guidelines in service processes. Finison et al. [9] and Sellick [16] discuss fundamental control chart theory in the context of implementing SPC charts in healthcare applications. Does et al. [7] also notes the need for commitment of top management before the initiation of an SPC project.

Sulek [17] argued that the under-utilisation of statistical quality control techniques in the service industry results from an incomplete conceptualization of service quality. She introduced a systems framework for service process quality which is used to diffuse popular arguments against the use of statistical quality control in services. MacCarthy and Wasusri [13] gave an excellent review in the literature of non-manufacturing SPC uses.

In this paper, we introduce some indices for measuring the ability of the sale's process of a Hellenic commercial company in order to apply statistical process control and monitoring. Statistical process control techniques are widely used in industry. The most common process control technique is control charting.

III. Shewhart Type Control Charts

A Shewhart type control chart is a graphical display of a process or a product quality characteristic that has been measured or computed from a sample versus the sample number or time. The basic characteristics of a univariate Shewhart process control chart are the «Center Line» (*C.L*), the «Upper Control Limit» (*U.C.L*), and the «Lower Control Limit» (*L.C.L*).

The ordinary rule applied to a Shewhart type control chart for declaring a possible out-of-control condition in a manufacturing process is the occurrence of a point outside the control limits. For example, in Figures 1 and 2, control charts for controlling the mean and the variance of quality characteristics are given.

In addition, many sensitizing run rules have been suggested for the Shewhart control charts in order to make them more sensitive in the detection of drifts in the mean of the process.

There are two distinct phases of control charting, Phase I and Phase II. In Phase I, charts are used for retrospectively testing whether the process was in control when the first subgroups were being drawn. In this phase, the charts are used as aids to the practitioner, in bringing a process into a state of statistical in-control. Once this is accomplished, the control chart is used to define what is meant by statistical in-control. In Phase II, control charts are used for testing whether the process remains in control when future subgroups are drawn.

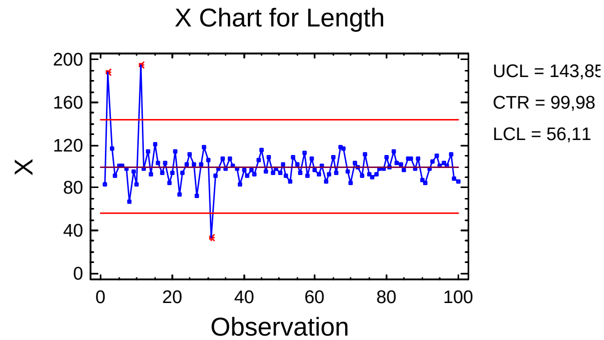

Figure 1: A classic Shewhart Type X control chart

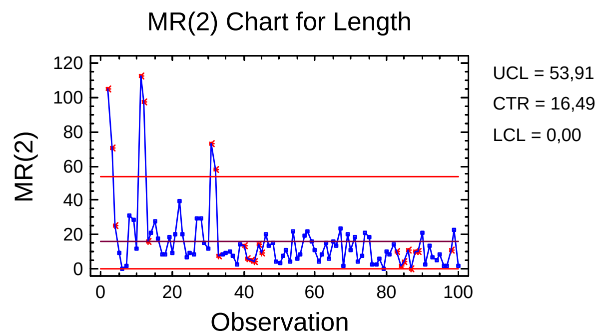

Figure 2: A classic Shewhart Type MR control chart

In Phase I, Shewhart control charts are very effective, since they are easy to construct and the interpretation is clear. Specifically, the meaning of a pattern appearing in a Shewhart type control chart is straightforward and has a physical meaning. These run rules were first proposed by the Western Electric Company [20].

IV. Methodology for Applying Control Charts to Sales Department

In this Section we present the basic ideas of applying Shewhart type control charts in sales data.

The company that concerns this study is a commercial enterprise in the area of furnishing. The department of sales consists of k salesmen. The data that we have in our hands concern the weekly sales of each one of the k salesmen, from July, 2 1974 till February, 25 2005 (n=5 five days a week measurements, and m =30 weeks in total). Furthermore, we define the weekly sales of each salesman by S_i^j for $i=1,2,..,30$ and $j=1,2,..,k$. The sum of sales of k salesmen will be symbolized with S_i^T for $i=1,2,..,30$. S_i^T is sum of the k random variables. The ratio of the sales of each salesman weekly as for the total sales of the week is defined as R_i^j for $i=1,2,..,30$ and $j=1,2,..,k$.

Thus, in order to check the stability and the attribution of each salesman we may apply *k* independent Shewhart type control charts for individual observations.

Furthermore, we will suppose that the sales of the *k* salesmen are independent among them. Actually, this cannot be valid, since the sales of each one of salesmen is influenced by the state of sector's market, which is reflected in the total sales of the company.

Another assumption that we make is that the weekly sales of each salesman are time independent. Such a hypothesis also may not be valid because of the fact that the sales are influenced from seasonality in the particular market. Finally, we suppose that the sales follow the normal distribution. This hypothesis may be verified.

Applying Shewhart type control charts for individual observations S_i^j in each one of the *k* salesmen, ignoring the cross-correlation and also ignoring the autocorrelation of measurements, we may drive the wrong conclusion that the sales' activity is out-of-control. In Figure 3, the control chart for individual observations for controlling the mean weekly sales as well as in Figure 4, the appropriate control chart for monitoring the variance of sales' activity for the salesman *D* are given.

In order to take into account the cross-correlation among variables, a multivariate control chart may be applied. This control chart is known as the T^2 Shewhart type control chart (Hotelling [10], Bersimis [5]).

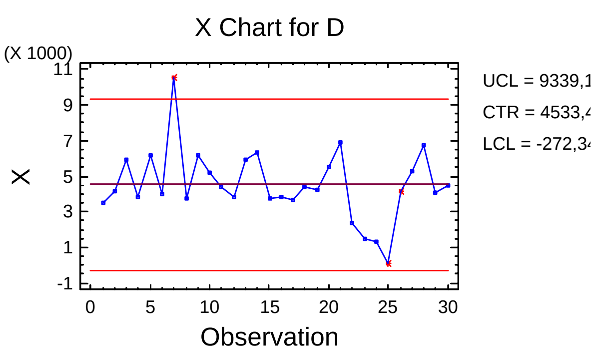

Figure 3: The control chart for controlling the weekly (mean) sales Salesman D.

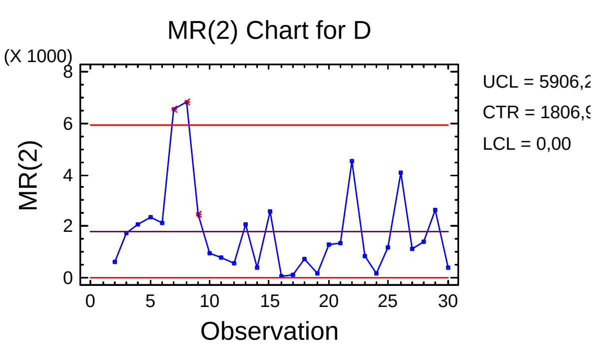

Figure 4: The control chart for controlling the dispersion of the weekly (variance) sales Salesman D.

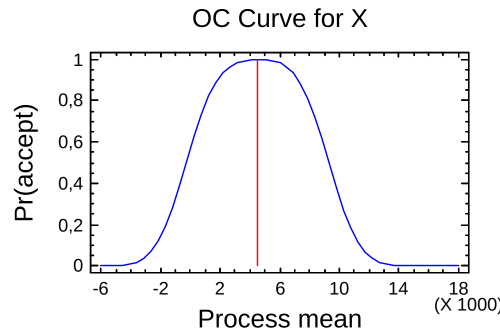

Figure 5: The Operating Characteristic Curve of the *X* control chart

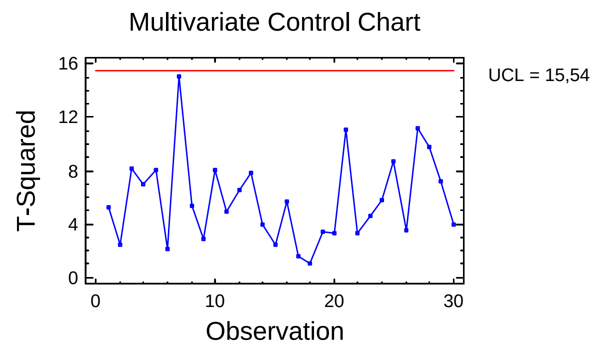

Figure 6: The control chart for controlling the weekly (mean) sales of all the salesmen.

As it appears in Figure 6, the sales of *k* salesmen actually are under a stable state, meaning that the sale process is statistically in-control.

Examing more carefully the T^2 control chart we may observe a non-random repeated pattern. This means that the T_i^2 values for $i = 1,2,..,30$ may be inside the control limits but they are far away from the line 0 (base of graph). This fact is owed in the autocorrelation. As we may easily conclude by observing Figures 7 and 8, there is a statistically significant autocorrelation among the values of the T_i^2.

Furthermore, when we face such a problem we have two choices. The first choice, is to model our observations making use of some suitable time series model. However, the problem of independent control of each one of salesmen will still remain. For this reason, we selected the second alternative, in order to control the quantity $R_i^j = \frac{S_i^j}{S_i^T}$.

The use of this quantity allows us almost the independent control of each salesman, since in this way we remove a significant part of the autocorrelation among observations.

This R_i^j indicator is the ratio of two related normal random variables and its distribution is known. Using the above defined ratio and by observing Figures 9 and 10, we may see (that the previous extracted conclusion that the sales process of the salesman D is out-of-control) is false.

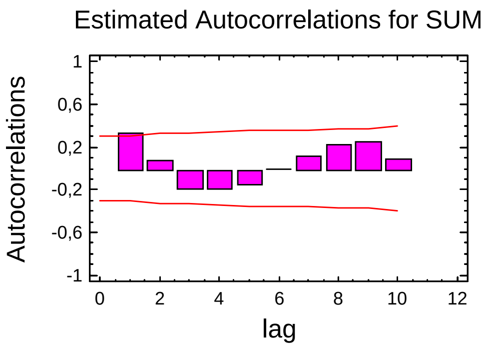

Figure 7: A classic Shewhart Type *MR* control chart

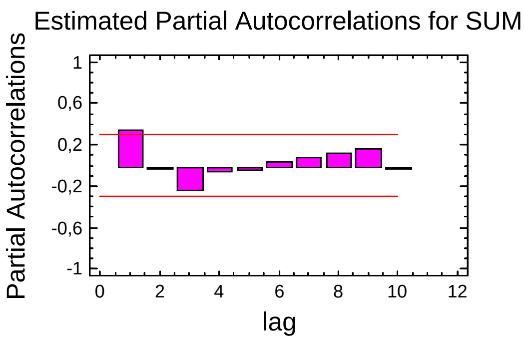

Figure 8: A classic Shewhart Type *MR* control chart

V. Comments And Topics for Further Research

The aim of this article is to present the potential uses of control charting in non-industrial processes. The use of the statistical quality control procedures in commercial companies or/and generally in non-industrial processes may be a valuable tool in the machinery of the managers in evaluating employees, departments, and services.

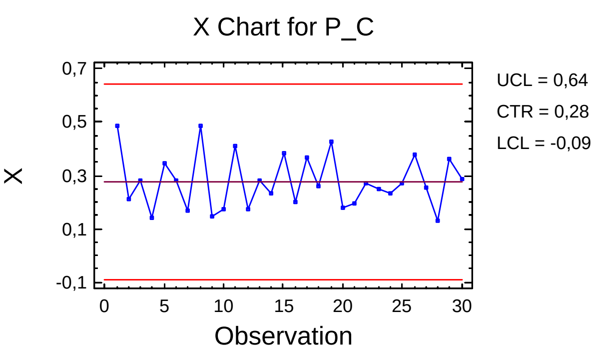

Figure 9: The control chart for controlling the weekly (mean) sales Salesman D based on the R_C.

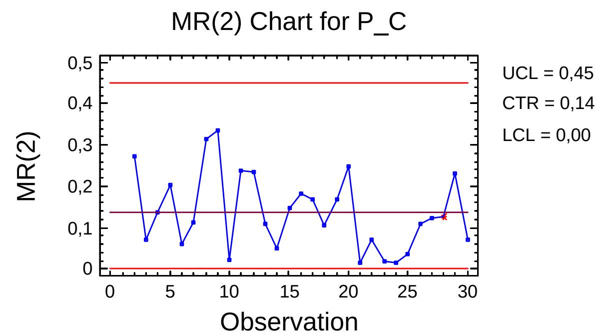

Figure 10: The control chart for controlling the dispersion of the weekly (variance) sales Salesman D based on the R_C.

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